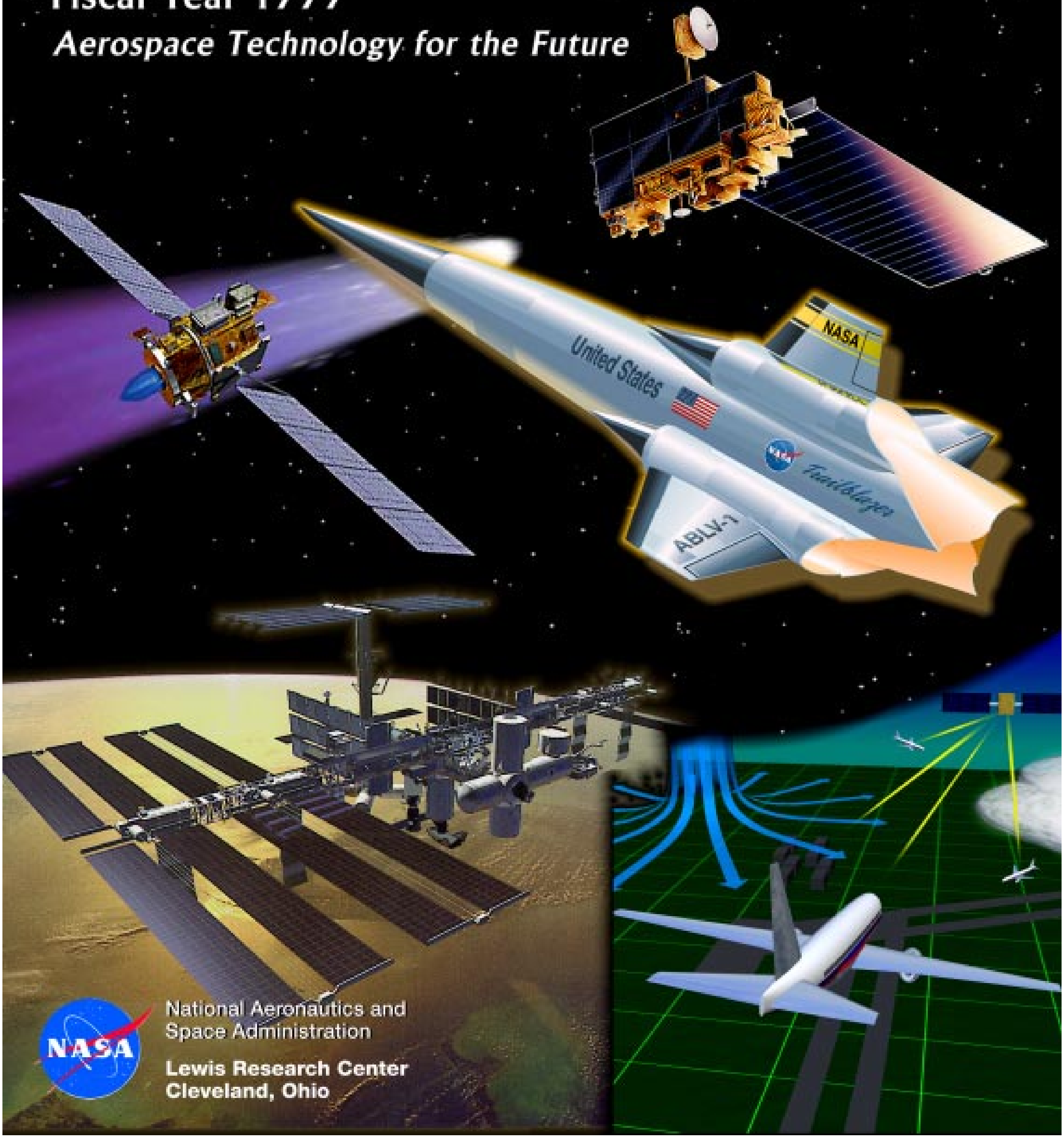
The NASA Lewis Research Center Strategic Implementation Plan

Fiscal Year 1999

Aerospace Technology for the Future



National Aeronautics and Space Administration

Lewis Research Center
Cleveland, Ohio

Center Director's Message

As members of the NASA Lewis Research Center, it is our honor and privilege to continue the Agency's tradition of innovation. I am proud to present to you the Fiscal Year 1999 Lewis Strategic Implementation Plan, which provides a complete picture of Lewis' contributions to NASA and more specifically Lewis' contributions to NASA's Enterprises. It presents a top-level view of how our skills and capabilities can be used to achieve the goals and objectives established to fulfill the Agency's vision.

The Lewis Research Center is putting in place a documentation process that begins at the Agency level with strategy, continues through this document with plans to implement that strategy, and cascades accountability through programs and projects to individual employees.

To position the Lewis Research Center to meet these challenges, it is essential that we clearly define our goals, wisely invest our capital resources, further develop our human resources, and strategically form partnerships and alliances. Our Nation's aerospace businesses, academia, the Department of Defense, and the Federal Aviation Administration are our primary external customers. NASA Headquarters and the other NASA centers are our primary internal customers. We also must be attuned to the needs of our stakeholders—Congress and the Administration—and must demonstrate our relevance to our beneficiaries and resource providers—the American public.

We therefore commit ourselves to implement this plan and practice the values of quality, openness, diversity, and integrity to meet the goals and objectives herein. This commitment will benefit NASA, our country, and the world.

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Director

Martin P. Kress
Deputy Director

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Deputy Director for Operations

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Director of Aeronautics

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Acting Director of Research and Technology

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Robert E. Fails
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Director of Safety, Environment, and Mission Assurance

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Lower Right: Aviation System Diagram—Represents Lewis contributions to Aeronautics and Space Transportation Technology

Foreground: Proposed Lewis-designed hypersonic vehicle "Trailblazer"—To be built early in the next millennium; represents Lewis synergy in aeronautics and space and Lewis' pioneering spirit

Introduction

The Government Performance and Results Act of 1993 requires that agencies conduct long-term strategic planning, measure program outcomes, and be accountable for achieving program results. Accordingly, NASA has developed a strategic plan that articulates its activities, goals, customers, and methods for achieving success.

The purposes of the NASA Lewis Research Center Strategic Implementation Plan are to

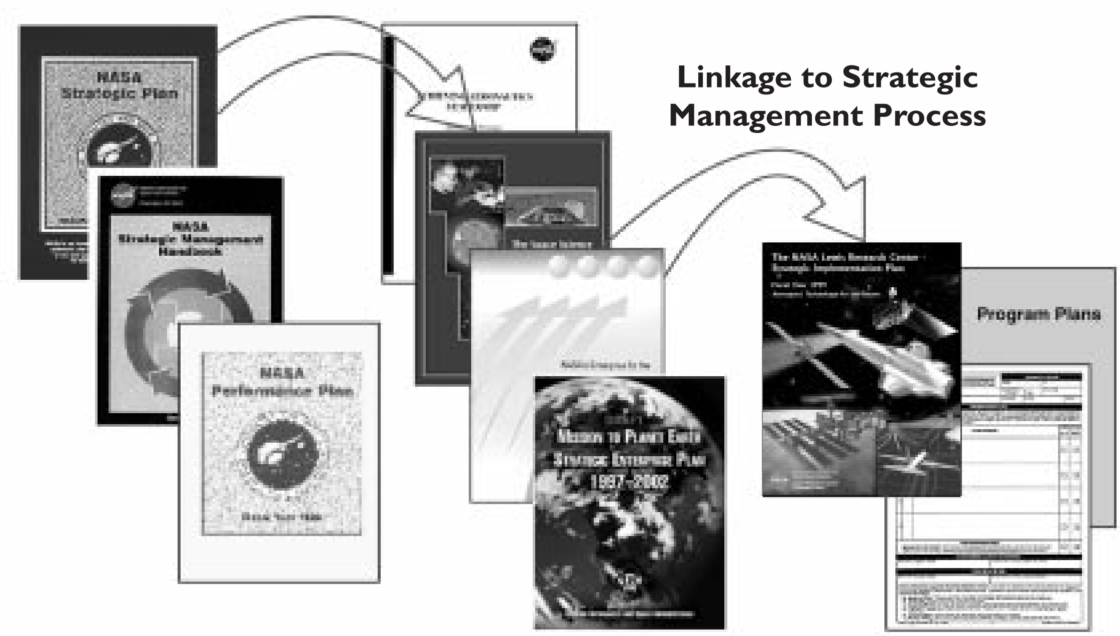
- Delineate the means by which we will achieve the goals and objectives set forth in the NASA Strategic Plan
- Communicate to Lewis employees their contributions to the Agency and the Center
- Assure our customers and stakeholders that their needs are being addressed
- Provide the major milestones that will be evaluated as part of the overall Agency Performance Plan

The near-term goals in this plan correspond to NASA's official 5-year budget plan and include all major Lewis commitments to NASA Enterprises, NASA centers, other agencies, and other external customers. The mid- and long-range objectives will be executed in time frames that exceed the current budget authority, although they represent a strategic direction consistent with the Agency vision and mission and with the Center mission and roles. These will be further defined and converted to short-term objectives for implementation as programmatic decisions are made.

The successful implementation of this plan rests with all employees and senior management and depends on the values that bind them together and are incorporated in every aspect of our operations. Progress towards programmatic goals and objectives will be assessed through continuous, active monitoring and measurement and will be reported during Center Program Management Council meetings and program reviews. These will be conducted in accordance with NASA Policy Guidance 7120.5, NASA Program and Project Management Processes and Requirements. Progress towards crosscutting and/or institutional process goals and objectives (or program goals that are crosscutting or institutional) will be reported and discussed during Management Information Meetings. The Lewis organization with primary responsibility for the objective and/or goal will collect, collate, and provide performance measurement data that will include all explanatory or qualifying remarks about such data. Trends will be monitored to ensure continued progress towards the achievement of the specific goals and objectives.

Relationship to Other Plans

In the following diagram, note that the elements of the NASA Strategic Plan cascade to the Lewis Strategic Implementation Plan and subsequently to lower-level programs, processes, and procedures at the Center.



The NASA Vision

NASA is an investment in America's future. As explorers, pioneers, and innovators, we boldly expand frontiers in air and space to inspire and serve America and to benefit the quality of life on Earth.

The NASA Mission

- To advance and communicate scientific knowledge and understanding of the Earth, the solar system, and the universe, and use the environment of space for research
- To explore, use, and enable the development of space for human and robotic endeavors in science and commerce
- To research, develop, verify, and transfer advanced aeronautics, space and related technologies

The Lewis Mission

As a diverse team working in partnership with government, industry and academia to increase national wealth, safety and security, protect the environment, and explore the universe, we develop and transfer critical technologies that address national priorities through research, technology development, and systems development for aeronautics and space applications.

Key Lewis Values

Sound values are needed to enable the Lewis team of highly skilled scientists, engineers, technicians, and support professionals to carry out the Center's mission and to accomplish the goals and objectives set forth in this plan. These values are *quality, openness, integrity, and diversity.* They guide the Center's approach to strategy, customers, employees, work processes and systems and to its becoming a model workplace.

Lewis Agency-Specific Mission: Aeropropulsion

Center missions identify the primary concentration of capabilities to support the accomplishment of Enterprise strategic goals.

The Lewis Research Center's Agency-specific mission is to develop, verify, and transfer air-breathing propulsion technology (hereinafter referred to as aeropropulsion) for subsonic, supersonic, hypersonic, general aviation, and high-performance aircraft and rotorcraft. In relation to its mission, Lewis also conducts fundamental research in propulsion-related materials, structures, internal fluid mechanics, instrumentation, controls, and systems. Aeropropulsion encompasses turbine engines, all varieties of intermittent combustion engines (compression or spark-ignited), electric engines, and all other types of engines used on aircraft.

Quality
- Customer focus
- Empowerment
- Continuous improvement
- Measurement

Openness
- Trust
- Communications
- Dialogue
- Partnerships

Goal
The Lewis Research Center, committed to becoming a model workplace, is guided by its key values to respect and value the entire workforce, recognize each individual's potential, support innovation in research, technology development, operations, administration, and management.

Integrity
- Fairness
- Authenticity
- Highest ethical standards
- Mutual accountability

Diversity
- Respecting differences
- Teamwork
- Synergy
- Innovation

Lewis Center of Excellence Responsibility: Turbomachinery

Centers of excellence have Agency-wide focused leadership responsibilities in a specific area of technology or knowledge, their capabilities and boundaries clearly defined by their charters.

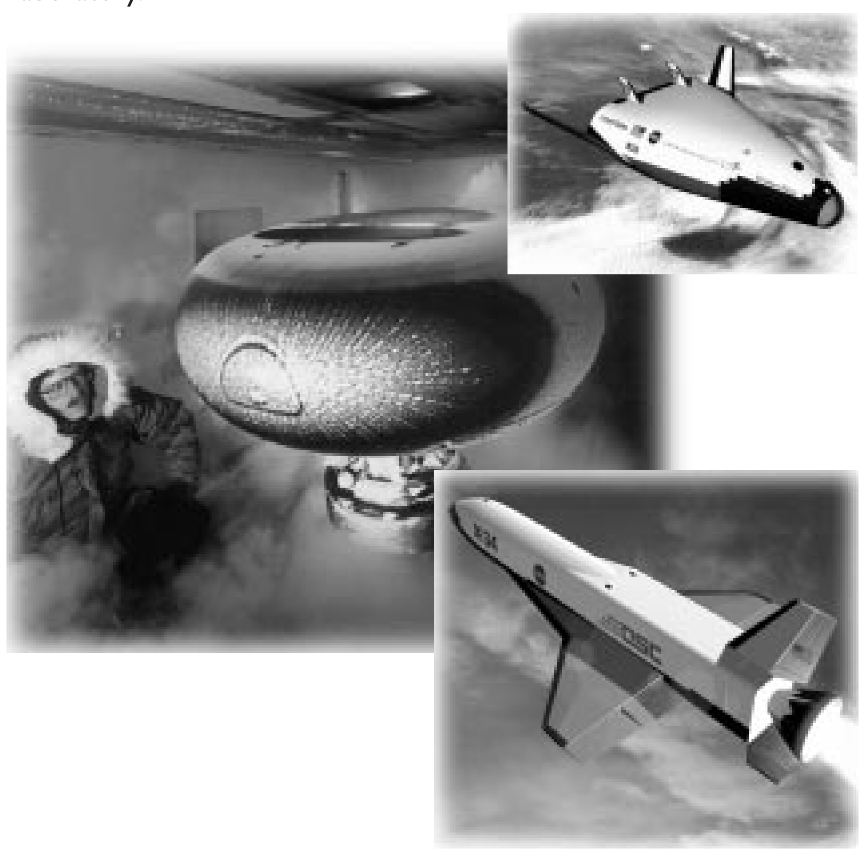
As NASA's Center of Excellence for Turbomachinery, Lewis' role is critical to advancing the Agency's aeronautics and space goals. The Center is committed to developing new and innovative technology to increase the competitiveness of U.S. industry and to leveraging its computational, analytical, and experimental expertise in turbomachinery to improve the reliability and performance, efficiency and affordability, capacity and environmental compatibility of current and future aerospace vehicles. Major benefits will be reductions in design cycle time and life cycle costs.

Applications requiring turbomachinery are air-breathing propulsion and space power systems, primary and auxiliary propulsion and power systems, onboard propulsion systems, and rotating machinery for pumping fuels. Rotating components include fans, compressors, turbines, and pumps; related components include combustors, bearings, seals, gears, inlets, nozzles, sensors, and actuators. Associated disciplines include materials, structures, lubrication, acoustics, aerodynamics, heat transfer, computational fluid dynamics, combustion, cryogenics, icing, and controls.

Lewis Program Responsibilities: Propulsion Systems and Aerospace Power Systems Research and Technology

Lewis has full responsibility for NASA's Propulsion Systems Research and Technology (R&T) Program, one of six Base R&T programs within the Aeronautics and Space Transportation Technology Enterprise. This program focuses on maintaining U.S. superiority in engine development and ensuring the long-term environmental compatibility of propulsion systems. The program addresses critical propulsion technology needs across a broad range of aircraft classes, including subsonic transports, high-speed civil transports, general aviation and commuter aircraft, high-performance aircraft, rotorcraft, and hypersonic vehicles. The objective of the Propulsion Systems R&T program is to develop and advance multidisciplinary propulsion technologies that can form the basis for future focused programs or can be transferred to industry and other end users.

In June 1998, Lewis was designated by the NASA Administrator as the Agency's Lead Center for Aerospace Power Systems Research and Technology. This area is crucial to future NASA missions and potential new initiatives and should benefit aeronautics and space and support all NASA enterprises. Responsibilities include leadership and management of advanced power systems research and technology development and where appropriate, support to NASA's power system development efforts. In these areas, Lewis will work closely with NASA's mission centers (Goddard, Johnson, and Marshall) and the Jet Propulsion Laboratory.



Lewis Support to the Four NASA Enterprises

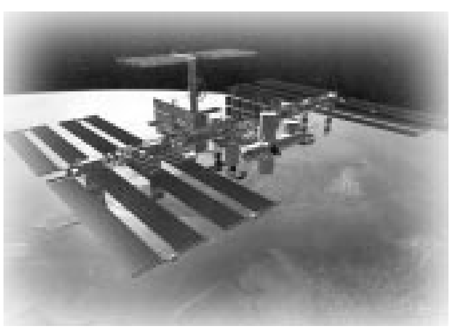
Programmatic Assignments: The Lewis Research Center institutionally reports to the Aeronautics and Space Transportation (ASTT) Enterprise, but it supports all four NASA Enterprises.

Agency-wide Responsibilities
- Lead Center
  - Spectrum management
  - Small Business Technology Transfer and Research contracting
  - Small Business Innovation Research contracting
  - Environmental information systems
- Principal Center
  - Workgroup hardware and software
  - Aeronautics exhibits
- Commercial communications program management and liaison to Space Operations Management Office

Aeronautics and Space Transportation Technology (ASTT)

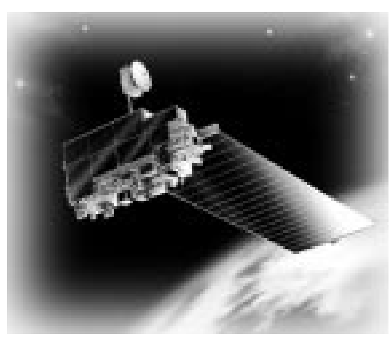
- Propulsion systems R&T
- High Speed Research: propulsion
- Advanced Subsonic Technology: propulsion
- Aviation Safety
  - Accident mitigation
  - Weather-related accident prevention: aviation weather information/advanced data link, icing
- Rotorcraft R&T: low-noise technology
- Information Systems R&T: propulsion simulation, controls, and instrumentation
- High-Performance Computing and Communications: propulsion applications
- Flight Research R&T: Environmental Research and Sensor Technology (ERAST)
- Airframe Systems R&T: system study and analysis
- Airspace Operations Systems R&T: aeropropulsion
- Aviation System Capacity: advanced communications for air traffic management
- Advanced Space Transportation Technology: propulsion materials, aeropropulsion, turbomachinery technology, propellants, electric propulsion, propulsion system health management, power

Human Exploration and Development of Space (HEDS)



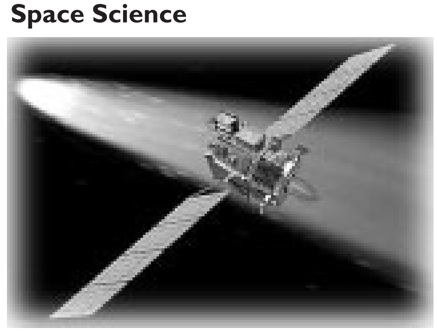
- International Space Station (ISS)
  - Electrical power
  - Fluid and combustion research facility
  - High-rate, broadband communications
- Commercial communications technology
- Microgravity research
  - Fluid physics
  - Combustion science
  - Acceleration measurement
- Exploration initiatives
  - Power
  - Onboard propulsion
  - Advanced space transportation propulsion concepts
- Space Shuttle upgrades: materials, propulsion and power

Earth Science



- Earth Observing Satellite (EOS) AM-1 launch services
- Power
- Onboard propulsion technologies
- Communications technology

Space Science



- Power
- Onboard propulsion technologies
- Communications technology

Contributions to NASA's Strategic Enterprises: Overview

The Lewis Research Center has provided critical support to and has developed advanced technologies for aeronautics and space. We believe that the synergy between these activities will provide the strong foundation needed to take us into the 21st Century. Integration of resources and reutilization of technologies across multiple missions and enterprises will provide a more effective way to harvest and reinvest our products and services.

NASA's four Enterprises guide our activities; each has identified a set of goals, objectives, strategies, and performance metrics in response to which we have developed this Strategic Implementation Plan.

In addition to this guidance, we adhere to a set of critical crosscutting processes by which we develop and deliver our products and services. In these four areas we are directed to

- Manage strategically
- Provide aerospace products and capabilities
- Generate knowledge
- Communicate knowledge

Our plan has been developed to define how Lewis contributes to the accomplishment of the Agency mission and has been organized by sections that specify our contributions by Enterprise and by crosscutting processes. What follows is our specific contribution to each.

Contributions to the Aeronautics and Space Transportation Technology (ASTT) Enterprise

To sustain global U.S. leadership in civil aeronautics and space transportation, the ASTT Enterprise developed a set of bold objectives presented in the brochure *Aeronautics & Space Transportation Technology: Three Pillars for Success*. The three pillars—Global Civil Aviation, Revolutionary Technology Leaps, and Access to Space—encompass 10 enabling technology objectives to revolutionize air and space transportation technology. Lewis' pivotal role in all three pillars is to make air and space transportation more affordable, environmentally compatible, and safe. Five NASA centers play key roles in implementing the three pillars: the Lewis, Langley, and Ames Research Centers, the Dryden Flight Research Center, and the Marshall Space Flight Center.

The following section outlines ASTT's goals and enabling technology objectives and the Lewis objectives that cascade from them. All major Lewis program milestones are included, the details of which can be found in the applicable Lewis Program Plans. For readability and consistency, all goals and objectives have been date normalized and chronologically sequenced by fiscal year and are followed by those for which no dates are associated. The objectives that do not have a defined time frame are either performed on a continuous basis or are in programs that are still being defined.

Pillar One: Global Civil Aviation

***ASTT Goal*—**Ensure an environmentally sustainable global civil aviation system of unquestioned safety and unparalleled affordability for the next century.

***ASTT Enabling Technology Objective 1*—**"Reduce the 1997 aircraft accident rate by a factor of five within 10 years, and by a factor of 10 within 20 years."

Lewis Objective

Reduce aircraft accidents related to icing, weather, poor visibility, and engine problems; develop technology to prevent and suppress aircraft fires.

*By the end of FY1999, complete flight tests in severe weather contions to build a data base for supercooled large droplets (SLD).
  - Characterize the SLD environment.
  - Characterize the effect of SLD ice accumulation on aircraft performance.
  - Acquire data to support the development of SLD weather forecast tools.

- By the end of FY1999, complete testing of a new rotorcraft helical gear train configuration to establish minimum lubricating conditions while maintaining ultrasafe operation.
- By the end of FY2000, complete and publish three-dimensional design guidelines for the control of gear crack paths and the prediction of crack growth rates in ultrasafe gears.
- By the end of FY2001, develop alloys for turbine blades and disks that are twice as crack resistant as current alloys.
- By the end of FY2001, release version 3.0 of the LEWICE icing computer code to industry.
- By the end of FY2001, complete proof-of-concept of technology and characteristics to limit fuel flammability after a crash.
- By the end of FY2002, complete integration of a mathematical model of aircraft handling performance into a simulator for simulated icing encounters.
- By the end of FY2002, complete flight evaluation of synthetic vision display concepts to reduce Controlled-Flight-Into-Terrain accidents in general aviation aircraft.
- By the end of FY2002, successfully demonstrate national capability for digital data link and graphical display of weather information.
- By the end of FY2002, complete development of new sensors and probe technologies for enhanced engine health monitoring to detect engine failure precursors.
- By the end of FY2003, successfully demonstrate a full-scale composite engine fragment containment system.
- By the end of FY2004, successfully demonstrate technology to prevent in-flight, fuel-rated fires and explosions.

***ASTT Enabling Technology Objective 2*—**"Reduce emissions of future aircraft by a factor of three within 10 years, and by a factor of five within 20 years."

Lewis Objective

Reduce the emissions of aircraft engines designed after1997 by a factor of three by the year 2007 and by a factor of five by the year 2017.

*By the end of FY1999, demonstrate a low-emission combustor that meets the 50-percent nitrogen oxide (NO_x) reduction goal for large commercial transport aircraft engines.

- By the end of FY2000, demonstrate "smart" turbomachinery concepts to minimize pollutants throughout the mission cycle.
- By the end of FY2000, demonstrate a low-emission combustor that meets the 50-percent NO_x goal for regional aircraft engines.
- By the end of FY2000, demonstrate in a sector combustor rig a low-emission combustor that meets the 70-percent NO_x goal for large transport aircraft engines.
- By the end of FY2001, demonstrate a full annular combustor that meets the 70-percent NO_x goal for large engines.
- By the end of FY2002, demonstrate concepts for the reduction of gaseous, particulate, and aerosol emissions from aircraft engines.

*These Lewis objectives have been identified by the NASA Administrator as critical near-term Agency objectives for Fiscal Year 1999.

- By the end of FY2004, demonstrate cost-effective combustor concepts to reduce NO_x emissions below 50 percent.
- By the end of FY2012, develop and demonstrate technologies for simple, efficient, and fault-tolerant aircraft engine designs that will reduce NO_x emissions by 80 percent and carbon dioxide (CO_2) emissions by 50 percent.

ASTT Enabling Technology Objective 3—"Reduce the perceived noise levels of future aircraft by a factor of two from today's subsonic aircraft within 10 years, and by a factor of four within 20 years."

Lewis Objective

Reduce the perceived noise of subsonic aircraft engines designed after 1997 by a factor of two by the year 2007 and by a factor of four by the year 2017.

- By the end of FY2000, validate technology to reduce community noise impact by 10 decibels (dB) relative to 1992 technology (engine source noise contribution is a least 6 dB).
- By the end of FY2001, validate noise reduction technology through large-scale component testing (engine tests).

ASTT Enabling Technology Objective 4—"While maintaining safety, triple the aviation system throughput, in all weather conditions, within 10 years."

Lewis Objective

Develop and demonstrate enhanced aviation system throughput by propulsion system enhancements for rotorcraft and an improved airspace communications infrastructure to support free flight.

- By the end of FY1999, provide an analysis and a preliminary design of contingency power concepts for civil tiltrotor aircraft and down-select the best concept for detailed design and analysis.
- By the end of FY2001, provide an engine system test data base for civil tiltrotor contingency power concepts.
- Define free-flight communications requirements and identify technology shortfalls.
- Conduct demonstrations and experiments to provide free-flight concept verification and technology confirmation.
- Develop selected high-risk, high-payoff, advanced free-flight communications technology.

ASTT Enabling Technology Objective 5—"Reduce the cost of air travel by 25 percent within 10 years, and by 50 percent within 20 years."

Lewis Objective

Reduce aircraft engine design, development, acquisition, and maintenance costs to help achieve a 25-percent reduction in 1997 air travel cost by the year 2007 and a 50-percent reduction by the year 2017.

- By the end of the first quarter of FY1999, establish long-term plans and technology roadmaps for achieving the above reductions.
- By the end of FY1999, demonstrate improved turbomachinery design methods that will reduce turbomachinery design time by 40 percent.
- By the end of FY1999, demonstrate on a burner rig advanced ceramic matrix composite fabrication technology for turbine aircraft engines with inlet temperatures in excess of 2400 °F.
- By the end of FY1999, develop models and concepts that enable reductions in the cost and risk barriers for selected advanced turbine engine components.
- By the end of FY2000, demonstrate a 900 °F silicon carbide engine sensor.
- By the end of FY2001, develop an efficient unsteady computational fluid dynamics tool for designing high-load, high-efficiency, multistage turbomachinery.
- By the end of FY2001, provide validated design tools for turbomachinery components to reduce aircraft engine development time by 40 percent.
- By the end of FY2002, develop and demonstrate 650 °F polymer matrix composite material for aircraft engines.

Pillar Two: Revolutionary Technology Leaps

ASTT Goal**—**Revolutionize air travel and the way in which air and space vehicles are designed, built, and operated.

ASTT Enabling Technology Objective 6**—**"Reduce the travel time to the Far East and Europe by 50 percent within 20 years, and do so at today's subsonic ticket prices."

Lewis Objective

Develop environmentally compatible and economically viable engines for an advanced high speed civil transport (HSCT).

• By the end of FY2001, demonstrate through laboratory tests and analysis technologies that enable improvements in aircraft takeoff gross weight of 5 to 10 percent while maintaining High Speed Research (HSR) Program noise and emission goals.

• By the end of FY2002, provide materials that will enable the development of engine components that meet all the above emission and noise objectives while satisfying the weight, performance, and durability requirements for an economically viable HSCT.

• By the end of FY2002, develop critical component technologies for advanced HSCT engines that are environmentally compatible and economically viable.

• By the end of FY2003, demonstrate through laboratory tests and analysis technologies that will reduce noise and emissions relative to the conceptual HSR propulsion system.

• By the end of FY2006, provide a materials design data base necessary for the confident design and fabrication of a full-scale, operational HSCT engine.

ASTT Enabling Technology Objective 7**—**"Invigorate the general aviation industry, delivering 10,000 aircraft annually within 10 years, and 20,000 aircraft annually within 20 years."

Lewis Objective

Develop low-cost intermittent combustion and turbine engines and single-lever engine controls for general aviation aircraft.

• By the end of the first quarter of FY1999, complete assembly of the advanced general aviation turbine engine.

* By the end of the first quarter of FY1999, complete the assembly of the advanced general aviation intermittent combustion engine.

* By the end of FY1999, complete engine preflight ground tests for both engines.

• By the end of FY2000, develop and fly a general aviation intermittent combustion engine and a general aviation turbine engine that cost less than equivalent-power 1997 engines by factors of 2 and 10, respectively.

• By the end of FY2001, publish design guidelines, system standards, and certification data bases and methods for general aviation single-lever, power control propulsion sensor and control technology.

• By the end of FY2001, develop propulsion sensor and control technologies to enable one-lever engine control for general aviation aircraft.

ASTT Enabling Technology Objective 8**—**"Provide next-generation design tools and experimental aircraft to increase design confidence, and cut the development cycle time for aircraft in half."

Lewis Objective

Develop computing tools to reduce aircraft engine design and development time.

• By the end of FY1999, provide design tools that reduce the 1992 time-to-solution of propulsion components by a factor of 200.

• By the end of FY2000, develop ground and flight demonstration capabilities and methodologies for integrated air-breathing propulsion systems for experimental hypersonic vehicles and access to space.

• By the end of FY2001, provide a framework for distributive and collaborative computing for air-breathing propulsion systems to reduce the preliminary design time by 30 percent.

• By the end of FY2001, provide tools for a three-dimensional,

*These Lewis objectives have been identified by the NASA Administrator as critical near-term Agency objectives for Fiscal Year 1999.

steady-state, full engine simulation using distributed, heterogeneous computing to reduce the 1992 time-to-solution by a factor of 1000.

- By the end of FY2002, provide tools for integrating aircraft engine computation with experiments to reduce test time.
- By the end of FY2003, demonstrate advanced integrated air-breathing propulsion system concepts for hypersonic experimental aircraft flight.
- By the end of FY2006, develop and demonstrate, by means of experimental aircraft, advanced integrated vehicle-airframe-propulsion systems for hypersonic flight.

Pillar Three: Space Transportation

ASTT Goal—Achieve the full potential of space for all human endeavor through affordable space transportation.

ASTT Enabling Technology Objective 9—"Reduce the payload cost to low Earth orbit by an order of magnitude, from $10,000 to $1,000 per pound, within 10 years and by an additional order of magnitude, from $1,000's to $100's per pound, within 25 years."

Lewis Objective

Reduce the system cost contribution of access-to-space propulsion systems and associated subsystems while improving their performance, life, function, and operability.

- By the end of the first quarter of FY1999, develop and demonstrate combustion *wave* ignition technologies for reusable access to space propulsion systems.
- By the end of FY1999, develop and demonstrate X–33-scale advanced propellant densification technology.
- By the end of the first quarter of FY2000, develop and demonstrate combustion *laser* ignition technologies for reusable access to space propulsion systems.
- By the end of the third quarter of FY2000, develop and demonstrate advanced composite materials and composite material component architectures for reusable propulsion system components to the reusable launch vehicle (RLV) preliminary design level of maturity.
- By the end of the third quarter of FY2000, develop and demonstrate new reusable propulsion system health management logic and sensor technologies for first-generation automatic engine health assessment.
- By the end of the first quarter of FY2001, develop and demonstrate component technologies necessary to achieve operational-scale propellant densification.
- By the end of FY2001, develop critical propulsion component technology for a new air-breathing launch vehicle.
- By the end of FY2001, define an integrated reference vehicle concept for air-breathing access to space.
- By the end of FY2003, develop and demonstrate through ground testing an integrated propulsion system concept for air-breathing access to space.
- By the end of FY2006, in partnership with other centers and industry, develop and fly an integrated-airframe-propulsion system, air-breathing access-to-space demonstrator vehicle.
- By the end of FY2020, develop and demonstrate technology for an operational combined chemical and air-breathing propulsion system for a single-stage-to-orbit launch vehicle.

ASTT Enabling Technology Objective 10—"Achieve, within 15 years, a factor-of-10 reduction in the cost of Earth orbital transportation and a factor-of-2 to -3 reduction in propulsion system mass and travel time required for planetary missions. Within 25 years, enable bold new missions to the edge of the solar system and beyond by reducing travel times by 1 to 2 orders of magnitude."

Lewis Objective

Develop advanced spacecraft propulsion technology.

- By the end of FY2001, ground-test a 10-kilowatt (kW) Hall electric propulsion engine.
- By the end of FY2002, develop a cryogenic auxiliary propellant flight experiment to verify critical system design parameters.

- By the end of FY2002, demonstrate the injection of liquid oxygen into a hot hydrogen flow downstream of a supersonic nozzle to prove the performance of an integrated, in situ, low-cost, liquid-oxygen (LOX)-augmented, nuclear thermal rocket space transportation concept.
- By the end of FY2004, test advanced chemical fuels and investigate advanced cryogenic fuel management concepts to demonstrate theoretically derived, advanced propellant performance.
- By the end of FY2004, conduct experiments on magnetic nozzle physics and designs to demonstrate proof of concept.
- By the end of FY2005, flight-demonstrate cryogenic auxiliary propellant tank thermal and pressure control, vapor-free propellant acquisition, and liquid quantity gauging.
- By the end of FY2013, develop and demonstrate 50- to 100-kW electric propulsion technology components and systems.
- Investigate breakthrough propulsion physics.

Contributions to the Human Exploration and Development of Space (HEDS) Enterprise

The mission of the HEDS Enterprise is to explore space and reap the benefits that accrue from our increased knowledge. Lewis supports the HEDS Enterprise by providing expertise in several areas: research, development, and planning for the International Space Station; technology development for human missions of exploration; research in microgravity science, space power, onboard propulsion, space communications, and space transportation. This work is being accomplished in collaboration with the HEDS mission centers: the Johnson and Kennedy Space Centers and the Marshall Space Flight Center.

This section outlines the goals and objectives of the Human Exploration and Development of Space Enterprise and the Lewis objectives cascading from them. All major Lewis program milestones are included, the details of which can be found in the applicable Lewis Program Plans.

***HEDS Goal*—**Explore the role of gravity in physical, chemical, and biological processes.

***HEDS Objective*—**Enable the research community to use gravity as an experimental variable.

Lewis Objective

For the combustion science and fluid physics disciplines, enable the research community to use gravity as an experimental variable.

- By the end of the second quarter of FY1999, complete acceleration measurement support to principal investigators and analyze and publish the results of all combustion science, fluid physics, and materials science experiments conducted on MSL–1.

* By the end of FY1999, improve predictive capabilities for soot processes by at least 50 percent, based on analysis of MSL–1 data.

* By the end of FY1999, use the data obtained by the MSL–1 fluid physics experiments on suspensions of colloidal particles to answer fundamental questions in condensed matter physics.

- By the end of FY2000, on STS–107, successfully complete the fluid physics and combustion science investigations.
- By the end of FY2001, complete the eighth and final Spread Across Liquids (SAL) and Extensional Rheometry Experiment (ERE) sounding rocket flight and initiate follow-on sounding rocket investigations.
- Enable increased combustion system efficiency, reduced pollution, and mitigation of fire risks through insights gained and data uniquely obtained from microgravity experiments.
- Conduct ground-breaking basic research in reduced-gravity fluid physics and transport phenomena to provide a fundamental understanding of natural phenomena affected by gravity, thereby increasing the efficiency and effectiveness of space-based and industrial processes.

***HEDS Goal*—**Prepare to conduct human missions of exploration.

*These Lewis objectives have been identified by the NASA Administrator as critical near-term Agency objectives for Fiscal Year 1999.

HEDS Objectives—In partnership with the Space Science Enterprise, carry out an integrated program of robotic exploration of the solar system to characterize the potential for human exploration and development.

Explore and invest in enabling crosscutting technology and studies that can affordably open the frontiers for human space exploration where there is a compelling rationale for human involvement.

Lewis Objective

Develop power, communications, and onboard propulsion systems and advance the state of knowledge of reduced-gravity effects to enable human missions of exploration.

- Develop analytical tools and techniques to more accurately assess the performance of space power and propulsion systems to enable more accurate and cost-effective systems development (ongoing).
- By the end of the first quarter of FY1999, complete with the Keldysh Research Institute in Russia a cooperative investigation of the flammability of common spacecraft materials.
- By the end of the third quarter of FY1999, receive the phased-array antenna flight unit from Raytheon for the Direct Data Distribution (DDD) experiment and commence test and integration.
- By the end of the first quarter of FY2001, develop higher efficiency multiband-gap solar cells.
- By the end of the first quarter of FY2001, demonstrate second-generation modular power distribution units.
- By the end of FY2001 on the Mars 2001 Lander, complete a Martian dust and soil characterization experiment.
- By the end of the first quarter of FY2002, develop and successfully demonstrate space-based, phased-array technology for low Earth Orbit (LEO) applications.
- By the end of the first quarter of FY2002, develop and successfully demonstrate cost-effective, autonomous ground terminals for LEO spacecraft.
- By the end of the first quarter of FY2002, fly the Direct Data Distribution (DDD) experiment on the Space Shuttle to demonstrate the ability for data transport to and from the International Space Station (ISS) at rates up to 1200 Mbps without the use of the Tracking Data and Relay Satellite System (TDRSS).
- By the end of FY2002, complete the design of advanced, lightweight lithium-ion batteries.
- By the end of FY2002, investigate, simulate, develop, and demonstrate high-performance communications link and network technologies that would enable an improvement in communications capability and/or resource efficiency by at least an order of magnitude.
- By the end of FY2003, provide sufficient demonstration of technology development and design maturation in nuclear-solar power systems, nuclear-electric propulsion systems, cryogenic propellant long-term storage, and low-gravity management technologies to support the Agency timeline for decisions on future exploration initiatives.
- By the end of FY2010, develop and test a 50-kW, 2500-second-specific-impulse electric propulsion system.
- By the end FY2010, develop a planetary surface base station and transit vehicle power system designs and technologies to lower the launch and operational costs of space exploration.
- By the end of FY2015, develop propulsion, propellant, power, and in-situ resource utilization (ISRU) system technologies that will enable routine and affordable transportation to and commercial development of the Moon.
- By the end of FY2015, develop and demonstrate space power technologies (advanced power generation, storage, and management) and space propulsion technologies (advanced fuels, cryogenic management, advanced electric and thermal engines) that will reduce transit times and increase payload mass fractions and system reliability sufficient to enable human exploration missions to the Moon and Mars.
- Develop methods, data bases, and validating tests for material flammability characterization, hazard reduction, and fire detection and/or suppression strategies for spacecraft and extraterrestrial habitats.

- Advance the state of reduced-gravity fluid physics knowledge to allow the development of reliable and efficient heat transfer technology for space and extraterrestrial operations.
- Advance the state of reduced-gravity fluid physics knowledge to allow development of effective fuel management technology for space, extraterrestrial, and industrial operations.
- Advance the state of reduced-gravity fluid physics knowledge to enable dust control technologies and bulk materials handling for extraterrestrial habitats and/or in situ resource utilization.
- Develop and successfully demonstrate technology for advanced ISS communications in the K-band range.

***HEDS Goal*—**Continue to open and develop the space frontier.

***HEDS Subgoal*—** Develop and assemble the International Space Station (ISS) and utilize it to advance scientific, exploration, engineering and commercial activities.

***HEDS Objectives*—**Deploy and operate the ISS for research, engineering, and exploration activities.

Ensure the health, safety, and performance of space flight crews.

Lewis Objective

Support the deployment and operation of the ISS.

- Provide power system and hardware expertise to support the development, verification, acceptance, sustaining engineering, and operations of the ISS (ongoing).
- Analyze the ISS power system to determine end-to-end performance in stage and orientation-specific cases to support design analysis and verification analysis cycles; provide an analysis of power system performance during ISS operations to validate system and component performance (ongoing).
- By the end of the first quarter of FY1999, design, develop, build, and deliver hollow cathodes for inclusion in ISS plasma contactors.
- During FY1999, conduct in unique Lewis facilities thermal and/or vacuum testing of large ISS development and flight components and subsystems.
- By the end of the first quarter of FY2000, deliver more efficient dc/dc converters and more efficient and flexible remote power switches for the ISS and continue the development of advance power system components to reduce ISS electric power system operation costs, increase power available to users, and reduce logistics.
- By the end of the first quarter of FY2000, design, develop, build, and deliver a safety-critical manual switch for the ISS power system.
- By the end of FY2000, for deployment on UF–1, provide the Physics of Colloids in Space (PCS) experiment, integrate it in the ISS EXPRESS rack, and initiate experiment operations following system checkout.
- By the end of FY2000, complete the delivery of all Space Acceleration Measurement System (SAMS–II) equipment needed to support UF–1.
- By the end of FY2001, for deployment on flight 13A, develop and demonstrate flywheels as a replacement for batteries on the ISS and continue the development of flywheel energy storage technology.
- By the end of FY2001, for deployment on UF–3, develop and deliver the initial fluids and combustion facility (FCF) element, the combustion integrated rack (CIR).
- By the end of FY2001, for deployment on UF–3, develop and deliver the Droplet Combustion Experiment (DCE) and install and check out the experiment in the FCF-CIR. Initiate utilization of the FCF-CIR by conducting the DCE experiment and follow-on combustion investigations, averaging four to five per year after ISS assembly is complete.
- By the end of FY2002, for deployment on UF–5, develop and deliver the second FCF element, the fluids integrated rack (FIR).
- By the end of FY2002, for deployment on UF–5, develop and deliver the PHaSE 2 experiment and install and check out the experiment in the FCF-FIR. Initiate utilization of the FCF-FIR by conducting the PHaSE 2 experiment and follow-on fluid physics and transport phenomena investigations, averaging four to five per year after ISS assembly is complete.

- By the end of FY2003, for deployment on UF–7, develop and deliver the final element of the FCF, the shared accommodations rack (SAR), thereby completing the system and making it fully operational for U.S., international partner, and commercial utilization.
- Throughout ISS operations, analyze and interpret accelerometer data to characterize the microgravity environment of the ISS for the microgravity science principal investigations.
- Develop and provide advanced space communication technology and demonstrations to enable seamless, high-data-rate communication links between the ISS and commercial communication providers while providing increased capacity service to users.
- Perform plasma contactor performance validation using ground-tested and on-orbit data.
- Design, develop, build, and deliver low-flow, hollow cathodes for inclusion in ISS plasma contactors to at least double on-orbit life.
- Perform anomaly resolution using the Lewis power system testbed.

HEDS Subgoal— Provide safe and affordable access to space.

HEDS Objective— Improve the Space Shuttle Program operations by safely flying the manifest and aggressively pursuing a systems upgrade program.

Lewis Objective

Develop and demonstrate technologies for nontoxic Shuttle upgrades that require less maintenance and hazardous ground processing than current hypergolic propulsion systems.

- By the end of FY2000, provide concept design and technical expertise for air-breathing engines to enable a flyback Space Shuttle booster.
- By the end of FY2002, demonstrate LOX-ethanol auxiliary power unit (APU) technology.
- By the end of FY2002, demonstrate laser ignition for the orbiter maneuvering system (OMS), reaction control system (RCS), and APU combustion devices.

HEDS Goal—Aggressively seek investment from the private sector.

HEDS Objectives— Increase the affordability of space operations through privatization and commercialization.

- Promote investments in commercial assets as pathfinders in ISS commercial operations and reduce the cost of Space Shuttle operations through privatization, eventual commercialization, and lying payloads
- Reduce space communications and operations costs through privatization and eventual commercialization.
- Foster consortia of industry, academia, and government; leverage funding, resources, and expertise to identify and develop space commercial opportunities.

Share HEDS knowledge, technologies, and assets that promise to enhance the quality of life on Earth.

Lewis Objective

Enable the commercialization of space communication, power, onboard propulsion, and other aerospace technologies.

- By the end of the first quarter of FY2000, conduct experiments on the Advanced Communications Technology Satellite (ACTS), demonstrating concepts that will enable NASA's transition to commercial communications and satellite networking.
- By the end of the first quarter of FY2001, deorbit ACTS, close out the ACTS program, and complete and archive the ACTS technical analyses.
- Assure sufficient allocation and effective spectrum use by NASA.
- Provide planning and implementation leadership for NASA's transition to using commercial space communication systems.
- Identify the operational barriers to NASA's using commercial communications technologies and services.
- Demonstrate to the NASA Enterprises communication systems and technology that support NASA's transition to using commercial assets and services.
- Develop the technology that will enable high-performance communication links (space-to-space and space-to-Earth).

- Leverage NASA's investment in communication technology by providing advanced space communications architecture and components to other Federal agency missions.
- Enhance the U.S. satellite industry's competitiveness by developing and transferring precompetitive, robust communication technology.
- Develop and transfer advanced space power and propulsion technology to U.S. commercial communications and remote-sensing industries, which will enable them to manufacture satellite buses that have one-third the cost, mass, and volume of 1998 buses and thereby increase their competitive position.

Contributions to the Space Science Enterprise

The mission of the Space Science Enterprise is to explore the solar system: chart the evolution of the universe to understand its galaxies, stars, planets, and life; discover planets around other stars; and search for life beyond Earth. Lewis supports this Enterprise mission by providing advanced power, onboard propulsion, and space communication technology, all of which will lower mission costs and enable new capabilities. In addition, Lewis plays a major role in the crosscutting technology program that supports all the space enterprises and makes specific contributions to the Space Science mission-focused efforts in collaboration with Goddard Space Flight Center (GSFC) and the Jet Propulsion Laboratory (JPL).

This section outlines the goals of the Space Science Enterprise and the Lewis objectives cascading from them. All major Lewis program milestones are included, the details of which can be found in the applicable Lewis Program Plans.

Space Science Goals—

- Chart the evolution of the universe to gain knowledge of its galaxies, stars, planets, and life.
- Use robotic missions as forerunners to human exploration beyond low Earth orbit.
- Develop new critical technologies to enable innovative and less costly missions and research.
- Incorporate in Space Science missions and research plans to further educate the public and enhance their understanding of science.

Lewis Objective

Develop power, onboard propulsion, communication, and other advanced spacecraft technologies.

* By the end of the first quarter of FY1999, in support of the New Millenium Program, provide a 3200-second-specific-impulse ion engine (called NSTAR, NASA Solar Electric Propulsion Technology Application Readiness) to JPL for primary propulsion on the Deep Space 1 spacecraft. (This specific impulse is 10 times greater than that of current chemical propulsion systems.)

- By the end of FY1999, develop a reliable multicast-over satellite-links testbed.
- By the end of FY1999, complete K-band monolithic microwave, integrated-circuit-based phased array development, and by end the first quarter of FY2000, complete testing of it for use in direct data distribution experiments.
- By the end of the first quarter of FY2000, complete development of a 155-megabyte-per-second, radiation tolerant, modulator/encoder application-specific integrated circuit.
- By the end of the first quarter of FY2000, provide lithium-ion batteries for the Mars 2001 Mission.
- By the end of FY2001, develop a 32-gigahertz, 20-watt engineering model of a Traveling Wave Tube Amplifier for the Deep Space Network.
- By the end of the first quarter of FY2002, develop radio frequency component technologies that will open up the next frequency band (transmitting at 49 and receving at 40 gigahertz) to NASA and the Nation.
- By the end of the first quarter of FY2002, develop low-mass, long-life, chemical-based, attitude-control-system thrusters.
- By the end of the first quarter of FY2002, develop solar electric propulsion (SEP) gimbals to allow active control of SEP thruster positions.

*These Lewis objectives have been identified by the NASA Administrator as critical near-term Agency objectives for Fiscal Year 1999.

- By the end of FY2002, develop advanced SEP systems and thrusters.
- By the end of FY2002, develop advanced monopropellant systems and components meeting Pluto Express operational requirements.
- By the end of FY2003, develop technology for super-high-efficiency, lightweight, self-orienting, smart photovoltaic solar arrays.
- By the end of FY2003, develop advanced energy storage systems (including all-polymer batteries) and an integrated flywheel that provides both energy storage and attitude control.
- By the end of FY2004, develop advanced bipropellant systems and components.
- By the end of FY2015, reduce transit times and costs and increase by an order of magnitude payload mass fractions for science missions within the solar system.
- Develop power, energy storage, and onboard propulsion systems that support a two-thirds reduction in the mass, volume, and cost of the spacecraft bus of unmanned space vehicles.
- Develop reliable space power systems and perform defining science experiments for operation in harsh extraterrestrial environments (e.g., Martian dust, Jovian electron-proton belts, high temperatures).
- Develop low-temperature electronics that can operate without radioisotope heating units (RHU's) in the environment of the outer planets.
- Develop high-efficiency, thermal conversion technologies that reduce the quantity of radioisotopes required by conventional radioisotope thermal generators (RTG's).
- Develop precompetitive communication technologies that enable high-performance space-to-space and space-to-ground communication links for all NASA Enterprises.

Contributions to the Earth Science Enterprise

The Earth Science Enterprise is dedicated to understanding the total Earth system and the effects of natural and human-induced changes on the global environment. Advanced spacecraft technology being developed by Lewis is providing capabilities that will significantly enhance current or enable new Earth Science missions. Lewis' contributions are in advanced power, onboard propulsion, and space communications technology. The majority of the Lewis crosscutting technology efforts (conducted under the auspices of the Space Science Enterprise) are applicable to Earth Science Missions. In addition, Lewis is developing technology to meet specific Earth Science mission requirements in cooperation with Goddard Space Flight Center (GSFC) and the Jet Propulsion Laboratory (JPL).

This section outlines the goals of the Earth Science Enterprise and the Lewis objectives cascading from them. All major Lewis program milestones are included, the details of which can be found in the applicable Lewis Program Plans.

Earth Science Goals

- Expand scientific knowledge of the Earth system using NASA's unique vantage points of space, aircraft, and in situ platforms.
- Disseminate information about the Earth system.
- Enable the productive use of science and technology in the public and private sectors.

Lewis Objective

Develop power, onboard propulsion, communication, and other advanced spacecraft technologies.

- By the end of the first quarter of FY1999, procure and manage commercial launch services for the successful launch of the Earth Observing Satellite (EOS) AM–1.
- By the end of FY1999, together with GSFC, establish requirements for a flight modem and tracking terminal in support of the Earth Science System Pathfinders.
- By the end of FY1999, provide a pulsed plasma thruster for the Earth Observer 1 spacecraft.
- By the end of FY2000, deliver to GSFC the flight modem and tracking terminal in support of the Earth Science System Pathfinders.
- By the end of FY2000, develop high-efficiency solar cells to reduce solar array area and mass.

- By the end of FY2000, develop atomic-oxygen-durable solar array blankets to enable a 70-percent reduction in solar array blanket mass.
- By the end of FY2002, develop a low-cost, environmentally friendly, high-specific-impulse monopropellant system.
- By the end of FY2002, develop low-mass, pulsed and continuous, micronewton electric thrusters with 3- to 12-year lifetimes for precision pointing and formation flying.
- By the end of FY2002, develop high-specific-impulse, moderate-thrust, electric propulsion-chemical, low-mass, long-life thrusters for satellite stationkeeping and repositioning.
- By the end of FY2003, develop advanced energy storage systems, including lithium-ion batteries, and an integrated flywheel providing both energy storage and attitude control.
- By the end of FY2003, develop high-efficiency, low-weight, long-life, autonomous power management and distribution systems.
- By the end of FY2003, increase the modeling, characterization, prediction, and resistance of power system materials to the low Earth-orbit space environment.
- Develop power and onboard propulsion systems to support a two-thirds reduction in the mass, volume, and cost of unmanned space vehicles.

Lewis Crosscutting Process Objectives

The NASA Strategic Plan outlines the following crosscutting processes:

- Manage strategically
- Provide aerospace products and capabilities
- Generate knowledge
- Communicate knowledge

Lewis contributions to these processes include promoting customer outreach, collaborating with other NASA centers, federal, state, and local agencies, academia, and industry partners, making national alliances, and cost effectively managing test and computational facilities. The Center will continue to exceed its goals and lead the Agency in awarding contracts and grants to small businesses and minority educational institutions. Lewis will also continue to contribute to the definition and implementation of Agency initiatives such as the Integrated Financial Management System and selective outsourcing of information technology services. Lewis will further the use of NASA-developed science and technology in the public and private sectors and conduct its research without compromising public safety and security or the environment.

This section illustrates with milestones specific implementing activities related to these crosscutting processes. These activities are enabling functions that support the Lewis mission.

Process Objective 1

Form alliances and partnerships with other NASA centers, federal, state, and local agencies, academia, and industry.

- Coordinate space technology development programs among NASA, the Department of Defense (DOD), and the National Reconnaissance Office (NRO) through the newly formed Space Technology Alliance and identify opportunities for leveraging funds to enhance the support of NASA missions.
- Through participation in and leadership of the NASA-wide Joint Planning Teams, ensure that the Lewis space technology development programs are coordinated with other NASA technology development programs and that they enable the revolutionary exploration missions planned by the NASA mission centers.
- Provide leadership and technical support to the Interagency Power Group, which fosters the exchange and transfer of information regarding the development of advanced space power systems and has representation from all relevant U.S. government agencies.
- Implement a government-led communication alliance with academia and industry to create roadmaps and develop precompetitive technologies.
- Increase the value returned from the country's investment in microgravity research by managing the National Center for Microgravity Research on Fluids and Combustion to provide a focal point for the external academic and private sectors.

- Establish and help maintain the North American Icing Alliance.

Process Objective 2

Significantly enhance and expand Lewis' critical technical capabilities.

- Develop and implement a critical technical capabilities and/or a core competencies plan.
- Enhance and expand the dual career ladder.
- Optimize the NASA Lewis skill mix for effective, flexible operations.
- Implement a Strategic Research Fund (SRF) as part of the Center G&A (General and Administrative) account to support breakthrough research in new areas.
- Develop a coordinated management approach for all Lewis core research and technology programs (i.e., Director's Discretionary Fund (DDF), Small Business Innovative Research (SBIR), Strategic Research Fund (SRF)).

Process Objective 3

- By the end of FY2003, create and maintain a work environment free of discrimination, ensuring equal opportunity for all.
- Achieve a workforce representative of America's diversity.
- Eliminate EEO complaints by addressing issues and concerns through the Alternative Dispute Resolution process.

Process Objective 4

- Conduct triennial surveys of customer, employee, and labor union satisfaction and take corrective actions based on survey results.

* Achieve at least the following customer satisfaction ratings, based on a scale of 0 to 10:
  - 90 percent of the respondents rate their satisfaction at 5 or above.
  - 30 percent of the respondents rate their satisfaction at 8 or above.

- Develop similar performance measures for employee and labor union satisfaction.

Process Objective 5

Improve the effectiveness and usage of Lewis test and computational facilities.

† By the end of FY1999, achieve at least the following facility user satisfaction ratings, based on a scale of 0 to 10:
  - 95 percent of the facility users rate their satisfaction at 5 or above.
  - 80 percent of the facility users rate their satisfaction at 8 or above.

- By the end of FY1999, complete a decommissioning plan for the Plum Brook nuclear reactor.
- By the end of FY2000, implement the National Aeronautical Test Alliance.
- By the end of FY2001, highly satisfy at least 90 percent of all test facility users.
- By the end of FY2003, reduce test facility operating and maintenance costs by 10 percent.
- By the end of FY2003, reduce test facility cycle times by 25 percent.
- By the end of FY2003, expand the test facility user base to achieve a 90-percent facility utilization.
- Each year, establish at least one new partnership with a NASA information technology center or center of excellence.
- Each year, invest 20 percent of all facility funds in facility technology improvements.
- Improve and maintain facility capabilities by providing timely and cost-efficient engineering and construction services.

Process Objective 6

Obtain and maintain ISO 9001 certification.

- By the end of November 1998, complete certification documentation.
- By the end of March 1999, complete a preliminary assessment.
- By the end of July 1999, obtain ISO 9001 registration.
- Maintain ISO 9001 compliance and re-registration thereafter.

* This reflects Lewis' contribution to an ASTT Enterprise critical objective for Fiscal Year 1999.

† This reflects Lewis' contribution to a critical near-term Agency objective for Fiscal Year 1999.

Process Objective 7

Implement NASA's Integrated Financial Management System (IFMS).

- By the fourth quarter of FY2002, complete Phase I (core accounting and budget execution, budget formulation, travel, time and attendance, procurement, and employee information).
- By (to be defined in the future), complete Phase 1a (asset management and grants).
- By (to be defined in the future), complete Phase 2 (automated human resources and payroll).

Process Objective 8

Implement full-cost accounting and management.

- Comply with NASA's IFMS schedule for FY2000.
- In FY2000, identify institutional costs directly chargeable to programs and projects.
- In FY2001 and thereafter, operate in a full-cost mode.
- In FY2001, increase the number of services that are directly charged.

Process Objective 9

Ensure a smooth information system transition into the year 2000.

- By the end of the second quarter of FY1999, ensure that all software, hardware, firm ware, communications, and networking are year 2000 compliant.
- By the end of the second quarter of FY1999, ensure that all Lewis information technology applications accurately use date fields in manipulations and calculations, regardless of the dates being before or after the year 2000.
- By the end of the second quarter of FY1999, ensure that all date-dependent process control systems used in support areas, such as facilities and environmental controls, are year 2000 compliant.

Process Objective 10

Expand and improve Lewis science, math, and engineering educational programs and public outreach.

* Mobile Aeronautics Education Laboratory: by the end of FY1999, facilitate the replication of its contents at three new U.S. sites.

- Teacher preparation and enhancement: increase inservice training to foster a "multiplier effect" in science, math, and engineering.
- Student support: increase student participation and interest in science, math, and engineering from kindergarten through undergraduate grade levels.
- Curriculum support: increase the use of NASA instructional materials for the development of higher education curricula.
- Support systemic change: promote systemic change in math, science, and technology curricula at local, state, and national levels.
- Education technology: increase the development of products and services to facilitate the application of technology to the education process.
- Community and media relations: increase and enhance publicity on Lewis capabilities, accomplishments, and contributions.

Process Objective 11

Enable the productive use of science and technology in the public and private sectors.

- By the end of FY2005, increase NASA's reliance on commercial communication systems and foster the development of the remote-sensing industry; demonstrate seamless communications on the International Space Station information relays from spacecraft in low Earth orbit via communication satellites in medium Earth orbit and in geosynchronous Earth orbit.
- By the end of FY2010, develop and transfer coating and surface modification technologies to initiate the emergence of 10 new commercial products and 5 new industries.
- Lead NASA in the number of new technologies reported and in the number of Small Business Innovation Research (SBIR) and Small Business Technology

*This Lewis objective has been identified by the NASA Administrator as a critical near-term Agency objective for Fiscal Year 1999.

Transfer and Research (STTR) contracts awarded to small disadvantaged businesses (SDB).

- Increase the number of patents and licenses granted and new businesses incubated.
- Insure the publication of breakthrough discoveries in appropriate archived scientific and engineering journals.
- Enhance the transfer of microgravity research results to industry through participation in a focused outreach program established by the National Center for Microgravity Research on Fluids and Combustion.

Process Objective 12

Develop a comprehensive risk management methodology for research and technology development.

- Ensure that the methodology and all subsequent risk management plans comply with NPD 7120.4 and NPG 7120.5 and that they address safety, environmental compatibility, and security.
- By the end of the fourth quarter of FY1999, complete and disseminate the methodology.
- Utilize the Mission Assurance Program to improve the quality, timeliness, and cost-effectiveness of research products and services.
- Support implementation of the NASA Adminstrator's new Safety Initiative to establish NASA as having the best safety program in the Nation.

Process Objective 13

Increase performance-based contracting.

- Make all new contracts performance based.
- Train Lewis personnel in performance-based contracting.
- By the end of FY2001, obligate at least 90 percent of all procurement dollars to performance-based contracts.

Process Objective 14

Increase contracting with minority educational institutions and small businesses, including both disadvantaged and women-owned businesses.

- Increase efforts to identify eligible businesses to support set-aside decisions.
- By the end of FY2001, obligate $6 million to minority educational institutions.
- By the end of FY2001, obligate at least 35 percent of all procurement dollars to small businesses, including 25 percent to small disadvantaged businesses and 5 percent to women-owned small businesses.
- Increase small business participation in Lewis commercial technology programs.

Process Objective 15

Increase microprocurement contracting by Lewis user activities.

- By the end of FY2004, ensure that Lewis users effect 95 percent of all microprocurements.
- Expand the use of bankcards.
- Increase the electronic processing of solicitations, offers, and awards.

Process Objective 16

Implement the Outsourcing Desktop Initiative for NASA (ODIN).

- By the end of the first quarter of FY2000, complete ODIN implementation.
- Ensure that under ODIN, desktop, telecommunication, and networking systems will be comparable to or better than current systems with regard to response time, downtime, and other key performance measures.
- By the end of FY1999, establish a Lewis desktop customer satisfaction baseline rating and ensure that the ODIN contractor surpasses that rating by at least 10 percent in each of the first 3 years of the contract.
- Ensure that under ODIN, desktop, telecommunication, and networking costs will be no greater than the current full cost for current systems.

Process Objective 17

Expand equipment reutilization.

- By the end of FY2000, implement an information technology obsolescence plan.
- Internally, maximize cost savings by increasing reutilization (as opposed to warehousing) via acquisitions from other federal sources instead of by making new purchases.
- Externally, increase transfers of surplus property to educational institutions.

Appendix A
Lewis Program Points of Contact

ASTT Enterprise

Propulsion Systems
Research and Technology
Frank D. Berkopec (Acting) (216) 433–3942

High Speed Research:
Aeropropulsion
Robert Shaw (216) 977–7135

Advanced Subsonic Technology:
Aeropropulsion
Peter Batterton (216) 433–3912

Aviation Safety: Accident Mitigation
Douglas Rohn (216) 433–3325

Aviation Safety: Weather Accident
Prevention
Jai-won Shin (216) 433–8714

Rotorcraft R&T:
Low-Noise Technology
Timothy Krantz (216) 433–3580

Information Systems R&T:
Propulsion Simulation
John Lytle (216) 433–3213

Flight Research R&T:
ERAST Sensors
David Bents (216) 433–6135

Airframe Systems R&T:
System Study and Analysis
Timothy Wickenheiser (216) 977–7111

Advanced Space Transportation
Technology
Harry Cikanek (216) 433–6196

Advanced Communications
Konstantinos Martzaklis (216) 433–8966

HEDS Enterprise

International Space Station (ISS):
Electrical Power
John Dunning (216) 433–5298

ISS: Microgravity Research
Implementation
Jack Salzman (216) 433–2868

ISS: Fluid and Combustion
Research Facility Development
Thomas St. Onge (216) 433–3557

SOMO Commercial
Communications Technology
Pete Vrostos (216) 433–3560

Microgravity Science Research:
Fluid Physics
Fred Kohl (216) 433–2866

Microgravity Science Research:
Combustion Science
Stephen Simons (216) 433–5277

Microgravity Science Research:
Acceleration Measurement
Thomas Sutliff (216) 433–3887

Exploration Initiatives: Power
Raymond Burns (216) 433–5360

Exploration Initiatives: Advanced
Space Transportation
Stanley Borowski (216) 977–7091

Shuttle Upgrades
Heinz Wimmer (216) 433–5225

SS and ES Enterprises

EOS AM–1 Launch Services
Heinz Wimmer (216) 433–5225

Power
Raymond Burns (216) 433–5360

Onboard Propulsion
John Dunning (216) 433–5298

Communications Technology
James Budinger (216) 433–3496

On Behalf of all NASA

Lead Center for Spectrum
Management
Wayne Whyte (216) 433–3482

Commercial Communication
Program Management Liaison
James Bagwell (216) 433–3502

Lead Center for SBIR/STTR
Contracting
Walter Kim (216) 433–3742

Principal Center for Workgroup
Hardware and Software
William Naiman (216) 433–9330

Principal Center for Aeronautics
Exhibits
Robert Romero (216) 433–5538

Lead Center for Environmental
Information Systems
Daniel White (216) 433–3103

Appendix B
Lewis Institutional Points Points of Contact

Office of the Director
Director
Donald J. Campbell (216) 433–2929
Deputy Director
Martin P. Kress (216) 433–2962
Deputy Director for Operations
Julian M. Earls (216) 433–3014
Chief Scientist
Marvin E. Goldstein (216) 433–5825
Director of Diversity
Phillip R. Walker (216) 433–2486

Chief Counsel
William Sikora (216) 433–2318

Aeropropulsion Research Program Office
Frank D. Berkopec (Acting) (216) 433–3942

Inspector General
Chester A. Sipsock (216) 433–8960

Plans and Programs
Olga Gonzalez-Sanabria (216) 433–5252

Equal Opportunity Programs
Belinda M. Roberts (216) 433–2323

Chief Financial Officer
Robert E. Fails (216) 433–2977

Human Resources
Maury L. Blanton (216) 433–2515

Safety, Environment, and Mission Assurance
Vernon W. Wessel (216) 433–2350

Acquisition
Julian M. Earls (Acting) (216) 433-3014

Aeronautics Directorate
Director
Carol J. Russo (216) 433–2965
Deputy Director
Arun K. Sehra (216) 433–3397

Research and Technology Directorate
Director
Lawrence J. Bober (Acting) (216) 433–3944
Deputy Director
Lawrence J. Bober (216) 433–3944

Space Directorate
Director
Gerald J. Barna (216) 433–5308
Deputy Director
Rudolph L. Saldana (216) 433–2970

Engineering and Technical Services Directorate
Director
Jose M. Vega (Acting) (216) 433–5453
Deputy Director
Jose M. Vega (216) 433–5453
Plum Brook Management
Robert P. Kozar (419) 294–3236
Chief Information Officer and Computer Services
Sasi K. Pillay (216) 433–9300

External Programs Directorate
Director
John M. Hairston, Jr. (216) 433–8686
Educational Programs
JoAnn Charleston (216) 433–2957
Community and Media Relations
Linda Dukes-Campbell (216) 433–8920
Commercial Technology
Lawrence Viterna (216) 433–2966